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A SIMULTANEOUS ESTIMATION MODEL OF AIR FORCE ACCESSION AND RETENTION

Brice M. Stone
Thomas R. Saving
Kathryn L. Turner

Metrica Incorporated
8301 Broadway, Suite 215
San Antonio, TX 78209

Larry T. Looper
Sheree K. Engquist, Capt, USAF

HUMAN RESOURCES DIRECTORATE
MANPOWER AND PERSONNEL RESEARCH DIVISION
Brooks Air Force Base, TX 78235-5000

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LARRY T. LOOPER
Contract Monitor

WILLIAM E. ALLEY, Technical Director
Manpower and Personnel Research Division

ROGER W. ALFORD, Lt Col, USAF
Chief, Manpower and Personnel Research Division

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Brice M. Stone
Thomas R. Saving
Kathryn L. Turner
Larry T. Looper
Sheree K. Engquist

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8301 Broadway, Suite 215
San Antonio, TX 78209

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13. ABSTRACT (Maximum 200 words)

This research effort is an extension of previous work in single equation system modeling of the enlisted accession and retention markets. Since the two markets are related, proper model specification leads to the use of a simultaneous systems estimator. Data to estimate the model came from the time period of October 1979 through September 1987 and was chosen based on ecomonic and historical data availability. Four separate market equations were proposed and estimated: nonprior force accessions, prior service accessions, and first and second term reenlistments. A comparison of results using single-equation estimation with the simultaneous equation approach is made. The results presented show an improved estimation system based on statistical tests when the simultaneous estimator is used. Out-of-sample forecasting is also used to compare the two approaches. In addition a discussion of the endogenicity of quality of recruits and waiting time is presented in an appendix.

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PREFACE

The work documented in this technical report is an integral part of the Air Force Human Resources Laboratory research program to understand the relationship between the enlisted force accession and retention markets. It was accomplished as part of Project 7719, Force Acquisition and Distribution Systems and Task 771920, Manpower and Personnel Models. The ultimate goal is a more thorough understanding of the impact of wages and bonuses, force policies, and external economic conditions on accession and retention behavior resulting in more efficient use of Air Force compensation resources and a more experienced defense force.

The authors wish to thank Barbara Randall and Daryl Hand who performed an extensive programming and data analysis on this effort and thanks also go to Jonathan Fast for his insight and prime contractor program guidance. Lastly, we certainly want to recognize Kathy Berry and Carol Pulliam of RRC, Inc. for their word processing efforts in making this report a readable document.

SUMMARY

This report documents research to model the Air Force enlisted accession and retention markets. Previous Air Force research has considered these two markets to be independent and have treated them as such in the selection of the econometric estimation technique. The economic model presented in this paper considers two accession markets: non-prior service and prior service enlisted personnel; and two retention markets: first-term and second-term reenlistment. Two econometric estimation techniques were evaluated: ordinary least squares (OLS) and generalized least squares (GLS). OLS estimates the equation coefficients for each market separately while GLS attempts to determine the coefficient values by utilizing potential information flows between the four markets captured in the variance/covariance matrix. The time period used for estimating the models was FY 80 through FY 87. This period was one of high retention and relatively steady force levels until the later part of the period when force reductions and slight decline in retention rates were observed.

The results of the simultaneous estimation of the four markets show that the GLS estimator did improve the strength of the majority of the coefficients of the explanatory variables in each of the four market model equations when compared to the OLS estimates. This result means that the GLS estimates are more efficient and unbiased estimates of coefficient values and that a simultaneous estimator is more appropriate with interrelated markets such as exist in the accession and retention markets. In fact, some of the variable elasticities were underestimated by OLS by more than 10%, a finding that could result in costly underestimates of the impact of wages and bonuses on accession and retention. Several statistical tests of the GLS models are presented in the paper including out-of-sample forecasting and an analysis of the off-diagonal elements of the variance/covariance matrix, each test showing the simultaneous GLS model to be comparable to OLS or the more appropriate model. The appendix explores the use of waiting time variables, finding that the issue was not as significant as was found in earlier accession modeling work (Devany and Saving, 1982).

I. INTRODUCTION

For several years the Air Force Human Resources Laboratory (AFHRL) has been modeling the enlistment and reenlistment decisions of Air Force enlisted personnel. Previous military research efforts have attempted to use econometric models which account for the internal adjustments (e.g., use of selective reenlistment bonuses (SRB), retraining, career job quotas) made by personnel managers for the estimation of personnel demand and supply (Lakhani, 1987; Saving, Stone, Looper and Taylor, 1985; and Saving and Stone, 1983). In most of these cases, single equation estimators were used (Saving, Battalio, DeVany, Dwyer, and Kagel, 1980 and DeVany and Saving, 1982). To properly model the accession and retention markets, a simultaneously estimated system of equations representing both the internal and external forces affecting demand and supply of enlisted personnel is needed.

Section II presents an historical overview of the accession and retention behavior found during the sample period used for the analysis. Section III discusses the theory behind the simultaneous estimation of enlisted accession/retention. Section IV presents the results of estimating the accession and retention models separately and simultaneously. This section also compares the results from the single-equation estimator with the simultaneous equation approach to determine whether the simultaneous approach improves the fit of the models and/or affects the values for the estimated coefficients. Section V presents the conclusions of the analysis.

II. HISTORICAL OVERVIEW OF ACCESSION AND RETENTION, 1979 TO 1987

During the time period under consideration, October 1979 through September 1987, considerable market changes took place that affected enlisted accession and retention. The purpose of this section is to provide a general description of the changes in the exogenous conditions which took place during this period. In addition, the description of the accession and retention markets will provide insights into the simultaneous nature of these two enlisted markets.

During the 1980's, Air Force reenlistment rates reached historical highs, as can be seen in Table 1. For example, the first term reenlistment rate for fiscal year 1982 (FY82) was 55.5 percent and for FY83 was 64.5 percent, while reenlistment rates prior to FY81 were rarely over 40 percent. FY81 marked the beginning of a time period (FY81 to the present FY89) in which reenlistment rates averaged 60 percent. Second term and career reenlistment rates followed a similar historically high pattern (Quarterly Enlisted Retention Report, 1988). One factor behind these historically high reenlistment rates was the high youth unemployment rate (Table 1).

During the first few years of the sample period, the economic environment in the private sector provided limited career opportunities and much uncertainty for enlisted personnel who were at the first decision-making juncture in their career. As Table 1 indicates, employment opportunities in the sample period tended to limit the number of career options available to enlisted decision makers, especially first-termers. By the middle of fiscal year 1987, the unemployment rate had fallen to pre-1980 levels of 15 to 16 percent. Reenlistment rates did not adjust to the new employment opportunities in the latter part of the decade. One possible reason for the slow adjustment process may be that decision-makers' perceptions of their employment opportunities in the civilian labor force lagged behind actual opportunities. Although new and increased employment opportunities were available to decision makers, the conservative perception of the job opportunities induced decision makers to continue to reenlist at high rates.

The high unemployment rates and the substantial military pay raises in the early 1980's (11.7 percent in October, 1980 and 14.3 percent in October, 1981) coupled with the slow adjustment by individual reenlistment decision-makers to an improving economy were key reasons for the improved reenlistment rates of the 1980's. In addition, the average quality of new accessions rose as reflected in Table 1 by the proportion of AFQT 1's and 2's to all other recruits. This increase in quality was not unexpected given the economic conditions and military policies of the time period as well as the interdependency of accession and retention (DeVany and Saving, 1982).

Table 1. Sample Period Data by Fiscal Year

Fiscal Year	First Term Reenlistment Rate[a]	Percent AFQT 1's and 2's[b]	NPS Accessions[c]	Force Level[d]	Youth Unemployment Rate[e]	Early-outs[f]
FY79	37.92	35.6	66,616	458,953	16.1	5
FY80	35.73	34.9	71,838	455,909	17.8	0
FY81	41.94	38.6	76,918	466,520	19.6	0
FY82	55.47	39.6	67,538	476,472	23.2	1,481
FY83	64.53	44.4	60,489	483,022	22.4	4,324
FY84	62.28	45.8	60,011	486,410	18.9	1,137
FY85	56.14	44.2	65,017	488,603	18.6	4,136
FY86	66.63	45.8	64,400	494,666	18.4	7,972
FY87	57.03	48.6	55,000	495,244	16.9	9,081
FY88	69.49	51.8	41,200	466,865	15.3	23,558
FY89	66.08	52.8	43,450	462,831	14.6	5,161

[a] Derived from the AFHRL HAD Base retention data.

[b] Proportion of total NPS recruits categorized as mental category AFQT 1's and 2's. Data obtained from Air Force Recruiting Service, Randolph AFB.

[c] Data obtained from Air Force Recruiting Service, Randolph AFB.

[d] Data obtained from Quarterly Enlisted Retention Report: June 1988. USAF Enlisted Retention Branch, Randolph AFB.

[e] Data obtained from Bureau of Labor Statistics unemployment figures for the 16 to 19 year old civilian noninstitutionalized population.

[f] Derived from the AFHRL HAD Base retention data.

With improved reenlistment rates, accession flows declined nearly 47 percent from FY81 to FY88 (Table 1) as the proportion of AFQT category I's and II's increased from nearly 35 percent in FY80 to over 49 percent in FY87. Thus, the Air Force was in an enviable position in terms of accession quality since the declining force levels in the latter 80's offset the slight downturn in first term reenlistment behavior in FY88. High mental category recruits tend not to reenlist (Stone et al., 1989), but the Air Force was not adversely affected because the force level began declining in the latter 1980's. In fact, the early-out program for the Air Force became quite sizeable as personnel managers attempted to meet the desired end-of-fiscal-year force levels. For example, FY86 and FY87 had 7,972 and 9,081 first term early-outs, respectively, and 23,558 in FY88 (Table 1).

The high reenlistment rates of the 1980's were accompanied by slight increases in the Air Force's end-of-fiscal-year force levels through FY87. The force level increased approximately two percent from FY81 to FY82 and one percent from FY82 to FY83, declining to a 0.5 percent increase from FY84 to FY85, and increasing over 1.2 percent in from FY85 to FY86. The modest rises in the force level came to a dramatic halt in FY88 as the force level was reduced to its FY81 level with a 5.7 percent decline, followed by 0.85 percent decrease in FY89, as the effects of the Gramm-Rudman-Hollings budget cuts began to play a role in the Department of Defense (DoD) budget. This rise and fall in the force levels paralleled consistently high reenlistment rates, resulting in reductions in manning shortages and less dependence on selective reenlistment bonuses for first and second term reenlistments.

III. THEORY OF SIMULTANEOUS ENLISTED ACCESSION AND RETENTION

In an equilibrium model of the Air Force personnel market, enlistment supply is related to demand for personnel to replace those separating and is constrained to the end-of-fiscal-year force level. There are several distinctive features of such a model. First, both the **enlistment** and **reenlistment markets** are modeled **simultaneously**. Second, the mean length of enlistment and reenlistment periods is integrated with force level and personnel qualification considerations to determine the number of personnel by experience and qualifications. Third, the flows of enlistments and reenlistments that support these numbers are also determined.

The demand for labor can be depicted as a demand that a personnel inventory be maintained, i.e, that the Air Force desires to maintain a fixed enlisted force size. The flow of new accessions required to maintain this inventory depends on the size of the desired inventory and the turnover rate which is the inverse of the mean length of stay. The expected supply of accessions is a function of military compensation (directly), civilian wages (inversely), and the quality of accessions (inversely). At the same time, the mean length of stay is directly related to military compensation and inversely related to civilian wages.

For simplicity, assume that the mean length of stay is unaffected by the quality of the available civilian manpower pool. Thus, an increase in military compensation increases the mean length of stay, and an increase in civilian compensation reduces the mean length of stay. The demand for accessions depends on the force level to be maintained and the probability that personnel will leave the Air Force.

If one assumes that the number of members leaving can be represented by a stationary stochastic process, then,

$$L = F/s \tag{1}$$

where L is the steady state expected number leaving, F is the force size, and s is the mean length of stay. The probability that any single individual will leave the Air Force during any given time interval (P_L) is the reciprocal of the mean length of stay, i.e.,

$$P_L = 1/s, \tag{2}$$

which represents the turnover rate of personnel in the Air Force.

Substituting (2) into (1), the expected number of enlisted personnel leaving the Air Force is redefined as

$$L = P_L F. \tag{3}$$

An equilibrium force level requires that the number of new arrivals (accessions) equals the number of departures (separations). In a world of uncertainty, either the force level will do a random walk around its expected level, or wages must be constantly adjusting to insure the equality of accessions and separations (DeVany and Saving, 1982).

One method of maintaining the force level is to maintain a replacement inventory of recruits, (e.g., with the delayed enlistment program(DEP)). When a loss occurs, an accession can be drawn from this "outside" inventory to replace the loss, without waiting for the next applicant to arrive. The larger the outside inventory, the higher the probability that the force level will be maintained at its desired level at any future point in time. The Air Force can increase the number of waiting recruits by introducing higher wages so that applicants are willing to wait longer.

This constraint can be formalized by assuming that the probability that an eligible individual will agree today on a future service date, P_e, is a function of the waiting time, w, the entry level wages paid by the Air Force, m, and the wages of civilian jobs, c. This can be expressed as

$$P_e = P_e(w,m,c). \tag{4}$$

For simplicity, the probability of agreement to future service is assumed to be independent of quality. The expected waiting time is a function of military compensation and the desired force level, yielding the following equation:

$$w = w(m,F_d).$$

An increase in military compensation increases waiting time since the turnover rate falls and the arrival rate of new hires rises. An increase in the size of the desired force level reduces expected waiting time since it decreases the turnover rate and does not affect the arrival rate of new hires.

The effective supply of qualified applicants, i.e., the number of arrivals net of those dissuaded by the expected waiting time, is the product of the probability that an eligible individual will agree to future service in the Air Force, and the expected supply of entrants, S,

$$S_e = P_e S, \tag{8}$$

where S_e is the effective supply of qualified applicants. In equilibrium, the level of accessions must equal the level of separations (DeVany and Saving, 1982),

$$L = S_e, \tag{9}$$

which can be expanded to

$$F/s = P_e S. \tag{10}$$

Given an expected waiting time and fixed wages and force level, the Air Force is a quality-taker, and mean quality will adjust to the level that will support equilibrium. If quality can always adjust enough to make quantity supplied equal to quantity demanded, the quality-taking system will represent a constraint imposed upon the Air Force demand for accessions since the Air Force desires a certain quality level of personnel in its accession flows. Circumstances can arise in which the Air Force must lower its desired quality levels in order to attain fiscal year force level goals.

In the retention market the Air Force competes with the civilian sector on a more job specific basis than in the accession market. Enlisted personnel have received specific training and/or have reached a point in their military/civilian life-cycle career plan that requires the consideration of alternatives which were not available or desirable at the time of enlistment.

Assume that the Air Force consists of three groups by length of service. Group 1 consists of first-termers, group 2 consists of second-termers, and group 3 consists of career enlisted personnel. Assume that respective groups have mean lengths of stay, M_1, M_2, and M_3. Note that each of these mean lengths of stay will be less than the maximum or obligated range of length of service for each group, since losses occur during any cohort's movement through the system. The mean lengths of stay are functions of the relevant military and civilian compensation variables and quality standards.

The supply of entrants into groups 2 and 3, which are the relevant groups for retention analysis, depends on the same factors as the mean length of stay. Increases in the quality of new accessions will increase the number eligible to reenlist and accordingly increase supply to group 2. On the other hand, an increase in group 2 quality will reduce the supply of reenlistments. Increases in military compensation during the second or career terms will increase the supply of reenlistments, while increases in civilian wages will reduce the supply of reenlistments. The total force level will be the sum of those enlisted personnel in groups 1, 2, and 3. The group force levels influence and are influenced by the average experience level of the force.

Given that the total force level and experience distribution of the force (i.e., the proportion of second-termers and career enlisted personnel in the total force) are partly mandated by Congress through the budget process, new **accessions** must **equal** the **number** of **departures** from the first term group. In addition, the proportion of those reenlisting from group 1 must be just sufficient to maintain the losses from group 2 through both reenlistments into group 3 and losses to civilian jobs. Thus, for groups 2 and 3 the following must hold:

1. Reenlistments in group 1 must equal departures from group 2.
2. Reenlistments in group 2 must equal departures from group 3.

If, for example the total force level was allowed to decrease, while the experience distribution of the force remained fixed, the number of new accessions must then be less than the number of departures from the first term group. Similarly, reenlistments in group 1 must be less than departures from group 2 and reenlistments in group 2 must be less than departures from group 3. The demand for reenlistments is then influenced by the desired end strength in each group and the mean lengths of stay in these groups, which are in turn determined by the quality requirements and compensation considerations. The retention model displays an important aspect of the Air Force enlisted manpower system. Given force level and quality, the Air Force must set compensation in such a way that reenlistment goals are met. If wages, either through direct pay or reenlistment bonuses, are not set in this manner, then quality or the experience level of the force must change. In particular, in the event that Air Force compensation does not keep pace with the relevant civilian job markets, force quality and/or the experience level must fall.

Personnel managers must operate within a closed system, i.e., one in which there exists either minimal or no opportunity for lateral entry, and, thus, all departures are filled from within the system and all accessions to the system occur at the bottom, recognizing that the impact of the prior service program is small. This closed system is reflected in the fact that personnel managers meet force level goals through accession demands which offset separations and, at the same time, attain mandated force level increases or decreases. Thus, errors in projected retention rates require adjustments in accession demand as the fiscal year progresses to meet end-of-fiscal-year end-strengths.

Of course, the experience mix of the force is greatly determined by desired career manning levels. Adjustments in career manning shortages are made through changes in selective reenlistment bonuses, engendering higher retention rates and retraining, as well as increased accession levels by Air Force specialty (AFS). Adjustment in career manning overages are also made through changes in selective reenlistment bonuses, in some cases the elimination of the bonus, required retraining, decreased accession levels by AFS, and, finally, implementation of early-out programs. For some career fields, the Air Force finds that, in the absence of a reenlistment bonus, authorizations or manpower requirements cannot be met.

Because higher wages result in improved retention, any improvements in military pay have two effects:

1. The supply of eligible recruits is increased.
2. The number of recruits required to maintain any given force level is decreased since turnover is decreased.

The model presented above makes it clear that the accession market and the retention market are interdependent. There is significant feedback in both directions. Obviously, the number of accessions influences the gross number of first-termers available for reenlistment. Less obvious is the impact of Air Force pay scales on the number of second term and career individuals, which also affect the rate of new accessions. The effect of desired force levels impacts both retention and accession markets in a non-trivial way. These feedback mechanisms make the estimation of the simple supply relations difficult. Care must be taken to insure that observed accessions in a specific category are not the result of demand constraints.

Rationale for a Simultaneous System Estimator

A single equation estimation technique such as ordinary least squares (OLS) cannot account for these joint effects and, if used, will result in biased estimates of the supply effect of military compensation changes (Theil, 1971). The problem is more serious because variables, other than wages, also affect both demand and supply. The fact that the supply of eligible recruits and the Air Force demand for new accessions are determined by many of the same variables (e.g., military and civilian compensation, mandated force levels, unemployment, etc.) makes it virtually impossible to estimate supply effects without appropriate consideration of the demand effect.

Since common factors affect both retention and accession, the disturbances or residuals of the accession equations should be correlated with the disturbances or residuals of the retention equations. For example, a short-fall in expected retention (i.e., actual retention falls short of estimated retention) will result in actual accessions being above estimated accessions in order that the end of fiscal year force level be met. Since OLS would estimate the accession and retention equations independently and not consider the interdependency between the two equations, the correlation between the residuals of both equations would be ignored. If this relation between retention and accession is ignored, valuable information is not utilized, thereby failing to attain asymptotic efficiency. The single equation estimation deficiency can be overcome by estimating all the equations of the system simultaneously with a systems estimator The one selected for use in this study is generalized least-squares (GLS). GLS is an iterative procedure for adjusting the variance/covariance matrix of the simultaneous system of equations to take advantage of potential information flows between markets (Kmenta, 1971). It uses the estimated relationship between the retention and accession equations to improve the explanatory power of the estimated equations. If the actual equations are independent, then the GLS estimator will provide results identical to the OLS. The four-market model proposed in this paper will be specified with two accession equations, one for non-prior service and one for prior service recruits, and two retention equations, one for first term and one for second term reenlistment decisions. Numerous explanatory factors such as compensation, unemployment, consumer price index, quality, etc. are included in each market equation.

In addition to the question of simultaneity, a second issue briefly explored in this paper concerns the question of variable endogeneity. DeVany and Saving (1982), recognized the endogenous nature of force quality and DEP waiting time. The endogeneity of a variable refers to the extent to which the variable is determined by the system as it adjusts to reach equilibrium. The model estimated by DeVany and Saving (1982) assumed the Air Force fixes the desired force level and the military wage while quality and waiting time are allowed to vary. To determine if endogeneity is still prevalent, the present study employed a three stage least squares (3SLS) estimator to allow quality and waiting time to become endogenous variables in the NPS accession equation while the system of equations were being estimated simultaneously. The 3SLS estimate generally provided poorer statistical results for the NPS accession equation in terms of explanatory power and statistical significance of the coefficients. This suggested that the endogeneity of quality and waiting time in the management of the NPS accession flow was not as much a factor during the October 1979 to September 1987 time period as was previously reported for the 1974 to 1979 time period examined by DeVany and Saving (1982). Appendix A provides an expanded discussion of the 3SLS approach and its results.

IV. THE ESTIMATION OF THE SIMULTANEOUS MODEL

This section discusses the results of analyzing the Air Force personnel system with a simultaneous system of equations. The simultaneous estimation results will be compared with the ordinary least squares (OLS) estimation of the system to determine the benefits of using a simultaneous systems estimator.

Data Requirements

Data for the estimation of the non-prior service (NPS) accession equation were obtained from the accession file portion of the Historical Airman Data (HAD) Base with the population data from the Bureau of Labor Statistics. DeVany and Saving (1982) used the average time an airman spent in the delayed enlistment program (DEP) as the basis for the calculation of the average waiting time for NPS accessions. The calculation of the waiting time used the difference between the airman's date of enlistment (DOE) and his/her pay date. In June 1985, a policy change which affected the accounting of active duty time for pay purposes was implemented. The Air Force would no longer count the time spent in the DEP for pay purposes. Thus, the pay date and the DOE became the same date and waiting time indeterminate. An alternative source of data, the historical files from the military enlisted processing stations (MEPS), was used for the calculation of average waiting time. The new calculation of average waiting time was based on the difference between the DOE and the last chronological date of action recorded for the airman in the historical MEPS files.

Table 2 lists the variables used in the four equations, as well as their expected directional impacts on the dependent variables. The NPS accession rate (NPSRT) was defined as the ratio of the number of NPS accessions to the 16 to 19 year old youth population. The relative military to civilian wage (WR) accounted for basic pay, BAQ, BAS, and promotion opportunities over four years of active duty. The civilian wage was private nonagricultural wages. To account for adjustments in the recruiting of NPS accessions a variable was calculated (NPSGOAL) which represented how well the

Table 2. Definition of Model Variables

Variable*	Definition	Expected Sign
Dependent Variables:		
NPSRT	NPS accessions/16 to 19 year old population	n/a
RELRT1	First term reenlistments/First term eligible-to-reenlist decision-makers	n/a
RELRT2	Second term reenlistment/Second term eligible-to-reenlist decision-makers	n/a
PSRT	PS accessions/total eligible separations	n/a
NPS Accession Equation:		
QUAL	AFQT Category 1-2's/AFQT Category 3-8's	-
WAIT	Average time spent in the DEP(months)	-
EMP	Civilian noninstitutionalized employment rate	-
WR	Relative military to civilian wage	+
RECR	Number of Air Force production recruiters(thousands)	+
FLGOAL	Force level goal	-
NPSGOAL	NPS accession goal	-
PS Accession Equation:		
PSEMP	Civilian noninstitutionalized employment rate	-
RLWR1	Relative military to civilian wage	+
RECR	Number of Air Force production recruiters(thousands) (same as in NPS equation)	+
PSGOAL	Prior service accession goal	-
First Term Reenlistment Equation:		
RLEMP	Civilian noninstitutionalized employment rate	-
RLWR1	Relative military to civilian wage (same as in PS equation)	+
DECM1	Eligible/Ineligible first term decision-makers	+
EOUTS1	Number of first term early-outs(thousands)	+
Second Term Reenlistment Equation:		
RLEMP	Civilian noninstitutionalized employment rate (same as in First Term equation)	-
RLWR2	Relative military to civilian wage	+
DECM2	Eligible/Ineligible second term decision-makers	+
EOUTS2	Number of second term early-outs(thousands)	+

* All variables are expressed as ratios except where noted.

Air Force was performing relative to the fiscal year NPS accession goal. For each monthly time period, t, it represented how well the Air Force had attained its fiscal year goal through time period t-1. The time period of enlistment is represented as categorical variables (QTR1, QTR3, and QTR4) with QTR2 being a component of the constant term. These time variables are present in each equation.

Data for the estimation of the prior service (PS) accession equation were obtained from the retention portion of the HAD Base. Prior service accessions were recorded as transactions in the historical airman gain/loss (AGL) file which forms the basis for the retention portion of the HAD Base. The prior service accession rate was defined as the ratio of prior service accessions to total eligible separations over the last four time periods, i.e., time periods t, t-1, t-2, and t-3. Saving and Stone (1983) found that most prior service recruits exhibit a break-in-service of 48 months or less and, unless a waiver is received, were eligible to reenlist. In addition, separations with breaks-in-service of 90 days are eligible to receive part or all of the first term reenlistment bonus. The specification of the prior service accession equation accounted for the reenlistment bonus and the predominance of first term prior service accessions. Data for the estimation of the first term and second term reenlistment equations were also obtained from the retention portion of the HAD Base. The first and second term reenlistment rates were defined as the ratio of first (second) term reenlistments to total eligible first (second) term separations plus first (second) term reenlistments, i.e., total eligible-to-reenlist first (second) term decision-makers. The specification of the first and second term reenlistment equations accounted for the first (second) term reenlistment bonus and first (second) term early-outs from the previous four time periods. Early-outs reduced the size of the eligible-to-reenlist pool by allowing individuals who desire to separate to do so prior to the end of their term of enlistment.

Model Estimation Results

Results of the OLS and GLS estimation for each of the four markets are presented in Table 3. For the NPS equation, quality, waiting time, employment, the NPS accession goal, and the force

Table 3. OLS versus GLS Results

NPS Accessions		
Variable	OLS	GLS
Constant	4.3599	3.8760
	(4.58)	(4.65)
QUAL	-0.2253	-0.2018
	(-5.90)	(-6.04)
WAIT	-0.0343	-0.0360
	(-3.83)	(-4.59)
EMP	-1.1191	-1.1374
	(-3.76)	(-4.17)
WR	0.3316	0.4799
	(1.43)	(2.32)
RECR	0.0795	0.1279
	(1.21)	(2.17)
NPSGOAL	-0.2454	-0.2983
	(-2.48)	(-3.36)
FLGOAL	-2.9703	-2.6876
	(-3.66)	(-3.78)
QTR1	-0.0692	-0.0652
	(-4.71)	(-4.78)
QTR3	-0.0656	-0.0678
	(-4.92)	(-5.43)
QTR4	-0.0246	-0.0260
	(-1.83)	(-2.07)
R^2	0.6185	0.6584
Std. Error	0.0447	0.0423

PS Accessions		
Variable	OLS	GLS
Constant	0.3755	0.3917
	(3.33)	(3.69)
PSEMP	-0.8783	-0.9398
	(-7.84)	(-8.96)
RLWR1	0.2478	0.2736
	(6.21)	(7.65)
RECR	0.1076	0.1163
	(7.72)	(9.27)
PSGOAL	-0.0046	-0.0091
	(-0.99)	(-2.27)
QTR1	0.0025	0.0033
	(0.6164)	(0.85)
QTR3	-0.0053	-0.0054
	(-1.31)	(-1.40)
QTR4	-0.0151	-0.0154
	(-3.59)	(-3.85)
R^2	0.5648	0.5955
Std. Error	0.0138	0.0133

First Term Reenlistment		
Variable	OLS	GLS
Constant	0.4529	0.4667
	(0.78)	(0.84)
RLEMP	-2.4310	-2.3714
	(-4.17)	(-4.28)
RLWR1	1.1851	1.1880
	(9.88)	(10.41)
DECM1	0.9974	0.9110
	(3.78)	(3.78)
EOUTS1	0.0307	0.0311
	(5.83)	(6.24)
QTR1	-0.0337	-0.0342
	(-1.62)	(-1.72)
QTR3	0.0166	0.0162
	(0.83)	(0.85)
QTR4	-0.0178	-0.0176
	(-0.86)	(-0.89)
R^2	0.7711	0.7899
Std. Error	0.0671	0.0643

Second Term Reenlistment		
Variable	OLS	GLS
Constant	2.3361	2.4764
	(7.35)	(8.33)
RLEMP	-2.7666	-2.8515
	(-10.12)	(-11.07)
RLWR2	0.4564	0.4459
	(9.26)	(9.55)
DECM2	0.5166	0.4623
	(4.75)	(4.89)
EOUTS2	0.0287	0.0400
	(1.43)	(2.21)
QTR1	-0.0030	-0.0050
	(-0.31)	(-0.52)
QTR3	-0.0005	-0.0025
	(-0.06)	(-0.26)
QTR4	-0.0063	-0.0082
	(-0.63)	(-0.87)
R^2	0.8209	0.8348
Std. Error	0.0327	0.0314

( ) Values in parentheses are t-statistics. A t-statistic value of +/- 1.92 is statistically significant at the 95 percent (two-tail test) and a +/- value of 2.48 is statistically significant at the 99% level.

level goal were all statistically significant at the 99% level in OLS and GLS. Relative military to civilian wage and number of recruiters were statistically significant at the 95% level in the GLS but not in the OLS. The t- values for all non-binary variables improved from OLS to GLS, in some cases significantly. For example, the t-statistic for the relative military to civilian wage improved from 1.43 in OLS estimation to 2.32 in the GLS estimation, an increase of over 64.11%.

Changes in the values for the coefficients are more indicative of the gain in information from the use of the GLS estimator versus OLS (Kmenta, 1971). For example, the coefficient for the relative military to civilian wage (WR) in the NPS accession equation increased from the OLS estimate of 0.3316 to the GLS estimate of 0.4799, a 44.7% increase in the size of the coefficient. Since the mean value for the relative military to civilian wage was 1.2282 (See Table 4 for variable means and standard deviations), changes of 0.1 to 0.05 in the value of WR are more realistic. The impact of such an increase can be very significant. For example, a 0.05 increase in the value for WR resulted in a 0.02400 increase (GLS estimate) in the flow of NPS accessions. Assuming a mean population of 7,634,000 which is expressed in thousands in the denominator of the NPS accession rate, a 0.02400 increase in the NPS accession flow translates into approximately 183 additional monthly recruits, e.g., a 3.1% to 4.6% increase in the number of monthly active duty recruits based on accession flows of 6000 to 4000 per month.

Two other continuous variable coefficients in the NPS accession equation changed by more than 10% (became larger in absolute value) from the OLS estimate to the GLS estimate: the number of Air Force recruiters (60.88% from 0.0795 to 0.1279) and NPS accession goal (21.56% from -0.2454 to -0.2983). The binary coefficients for the fiscal year quarters changed only slightly. Thus, all coefficients of the NPS accession equation, continuous and binary, changed by some degree due to the GLS estimator.

The PS accession equation displayed large changes in relative military to civilian wage, number of recruiters, and PS recruiting goal while employment changed modestly. The first and second term reenlistment equations exhibited modest changes in employment and relative military to

Table 4. Sample Means and Standard Deviations for Model Variables

Variable*	Mean	Standard Deviation
Dependent Variables:		
NPSRT	0.35195	0.07231
RELRT1	0.57219	0.14024
RELRT2	0.78306	0.07735
PSRT	0.03095	0.20903
NPS Accession Equation:		
QUAL	0.90310	0.16595
WAIT(months)	5.38971	0.88063
EMP	0.80575	0.02148
WR	1.22820	0.05861
RECR(thousands)	1.53521	0.20625
PLGOAL	0.99786	0.00727
NPSGOAL	0.99097	0.05208
Prior Service Equation:		
PSEMP	0.93241	0.01395
RLWR1	1.28449	0.07136
RECR(thousands)	1.53521	0.20625
PSGOAL	1.22890	0.35331
First Term Equation:		
RLEMP	0.93316	0.01394
RLWR1	1.28449	0.07136
DECM1	0.84847	0.02900
EOUTS1(thousands)	0.76472	1.57380
Second Term Equation:		
RLEMP	0.93316	0.01394
RLWR2	1.25666	0.07986
DECM2	0.85918	0.03344
EOUTS2(thousands)	0.15650	0.24797

* All variables expressed as ratios except where noted.

civilian wage, but relatively large changes in the proportion of eligible-to-reenlist decision-makers and the number of early-outs.

Another measure of sensitivity between the explanatory variable and the dependent variable is the elasticity, a number which is defined as the percentage change in the dependent variable for a one percent change in one of the explanatory variables. To calculate the elasticities, the sample means for the explanatory variables were used since the elasticity formula can be expressed as the product of the coefficient of the explanatory variable and the ratio of the explanatory variable mean to the dependent variable mean. For example, the elasticity of employment in the OLS estimate of the NPS accession equation is -1.1191 times (0.80575/0.35195) which equals the -2.56 found in Table 5. Table 5 compares the elasticities of the explanatory variables from OLS and GLS. Thus, a one percent increase in the employment rate caused a 2.56 percent decrease in the NPS accession rate. The elasticity for the GLS estimate of the relative military to civilian wage is 1.675, higher than the 1.157 value from the OLS estimate and comparing favorably with the 1.590 value from the 2SLS results of the DeVany and Saving study (1982). This implies that a 1% increase in the relative military to civilian wage would result in a 1.675% increase in the NPS accession rate versus a 1.157% increase using the OLS estimate. Since the denominator in the NPS accession rate (the civilian noninstitutionalized population base) does not change significantly over short time periods (see Appendix B), the percentage change in the accession flow occurs primarily in the number of constant quality accessions willing to commit to active duty. Past studies have provided wage elasticities for NPS accessions which ranged from 0.46 to as high as 6.207 (Cook, 1970; Fechter, 1972; Grissmer, 1978; and Saving et al., 1980) using OLS with a variety of functional forms. Thus, the GLS estimate of 1.675 is consistent with past studies and tends to be slightly higher than most results from OLS studies.

The R^2s and standard errors presented in Table 3 indicate that the GLS estimates improved the explanatory power of each equation but does not indicate how well the system performed overall. McElroy (1977) defined an R^2 for a system of equations which has properties similar to the single

Table 5. Comparison of OLS and GLS Variable Elasticities

Variable	OLS Elasticity	GLS Elasticity
NPS Accession Equation:		
QUAL	-0.5781	-0.5178
WAIT	-0.5253	-0.5513
EMP	-2.5621	-2.6039
WR	1.1572	1.6747
RECR	0.3468	0.5579
FLGOAL	-8.4214	-7.6199
NPSGOAL	-0.6910	-0.8399
PS Accession Equation:		
PSEMP	-26.4860	-28.3127
RLWR1	10.2842	11.3550
RECR	5.3373	5.7688
PSGOAL	-0.1826	-0.3613
First Term Reenlistment Equation:		
RLEMP	-3.9646	-3.8674
RLWR1	2.6603	2.6669
DECM1	1.4790	1.3509
EOUTS1	0.0410	0.0416
Second Term Reenlistment Equation:		
RLEMP	-3.2969	-3.3981
RLWR2	0.7324	0.7156
DECM2	0.5668	0.5072
EOUTS2	0.0057	0.0080

equation R^2. Using McElroy's definition of a system R^2 and the results of the GLS estimates in Table 3, the estimated system R^2 was equal to 0.7876 with an F value of 41.7460 which is statistically significant at the 99% level. Thus, 78.76 percent of the variation in all of the system's dependent variables was explained by the GLS estimate of the equations.

In addition to the system R^2, two statistics, λ_{LM} and λ_{LR} (Judge, Griffiths, Hull, Lutkepohl, and Lee, 1985), were estimated to determine if the off-diagonal elements of the GLS system's variance/covariance matrix were statistically different from zero. As indicated earlier (Section II),if the off-diagonal elements of the system variance/covariance matrix are zero, the GLS estimates reduce to the OLS estimates. The values estimated for λ_{LM} and λ_{LR} were 44.99 and 34.01, respectively, which indicates that the off-diagonal elements of the GLS system's variance/covariance matrix are statistically different from zero at the 99% level. This lends additional support to the hypothesis that the effect of the information flows between the equations of the system, which is ignored by OLS estimates, is important as an accurate estimation of the coefficients of the system.

Out-of-sample forecasting is another method for comparing the OLS to GLS estimates. Two time periods were selected for out-of-sample forecasting, January 1979 through September 1979 and October 1987 through September 1988. Table 6 presents the results of forecasting using the OLS and GLS estimates for both periods. Three measures of forecasting credibility were used: root mean square error (RMSE), mean absolute error (MAE), and Theil's Inequality Coefficient (TIC). For an extended discussion of these three measures, refer to Appendix A of Stone et al., 1989. The GLS estimates performed better than the OLS estimates across all three statistics with the exception of the prior service accession equation which performed poorly for both OLS and GLS.

For the October 1987 through September 1988 time period, OLS performed better than the GLS across the four equations based on RMSE. The GLS forecasts tended to err more for time periods exhibiting substantial fluctuations in the dependent variable while providing more accurate predictions for the more normal monthly fluctuations. Theil's Inequality Coefficient for the OLS and GLS forecasts differed by less than one hundredths of a point. Thus, the out-of-sample predictions

Table 6. Out-of-Sample Forecasting: OLS versus GLS

Date	NPS Accessions		PS Accession		First Term Reenlistment		Second Term Reenlistment	
	OLS	GLS	OLS	GLS	OLS	GLS	OLS	GLS
January 1979 Through September 1979:								
RMSE	0.0783	0.0768	0.0093	0.0101	0.0810	0.0796	0.0193	0.0190
MAE	0.0544	0.0543	0.0085	0.0086	0.0750	0.0741	0.0169	0.0165
TIC	0.0908	0.0888	0.4443	0.5123	0.1206	0.1181	0.0156	0.0154
October 1987 Through September 1988								
RMSE	0.1230	0.1250	0.0194	0.0195	0.1469	0.1520	0.0505	0.0632
MAE	0.0983	0.0963	0.0154	0.0155	0.1173	0.1211	0.0389	0.0487
TIC	0.2869	0.2892	0.7071	0.7049	0.1031	0.1063	0.0315	0.0391

were slightly more accurate in FY88 for OLS versus GLS forecasts while the GLS forecasts generally performed better for the January 1979 through September 1979 time period. Since FY88 was a time period of large enlisted personnel reductions (5.73% reduction in the enlisted force or over 28,300 airmen), the FY88 time period exhibited institutional changes outside the scope of the estimated models (Stone, Looper, and McGarrity, 1989). Thus, the part of FY79 selected for out-of-sample forecasting may be more representative of the time period over which the estimation was performed.

V. CONCLUSION

Section IV presented the results of applying two simultaneous estimators to a system of equations which modeled the Air Force's accession and retention markets. The results presented in Section IV lead to several conclusions:

1. A systems estimator (GLS) provides estimates of system coefficients which differ by more than 10% for several variables versus the single equation estimated counterparts making use of elasticities based on GLS estimates more representative of true system inputs.

2. In general, T-statistics for GLS were more significant than were the OLS estimates.

3. Based on the significance of the variance/covariance matrix for the market system, the use of the GLS simultaneous systems estimator provided unbiased estimates of the coefficients compared to OLS.

The key issue supported by the results of this study is that information is being lost when single equation estimators are used to estimate wage elasticities for accession or retention. Coefficients and/or elasticities for relative military to civilian wages are understated by 10% or more. For the assessment of wage and bonus policy, a 10% underestimate can be costly for personnel planning as well as the annual Congressional budget process. Thus, since the single equation model is a misspecification of the system, forecasting with single equation estimates will not perform as well as forecasting with a fully specified model.

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APPENDIX A

Comparison of GLS and 3SLS

The difference between GLS and 3SLS lies principally with the existence and handling of endogenous variables (Theil, 1971). The GLS approach assumes that no endogenous variables are in the system and the system of equations is estimated simultaneously to take advantage of all the available information about the equations. The methodology employed for estimating the system of equations is the same for GLS and 3SLS with the exception of using the predicted values for the endogenous variables in the 3SLS approach.

As with GLS, if the interaction between accession and retention is not important, e.g., the disturbances are uncorrelated across equations, then the 3SLS results will mirror the two-stage least squares (2SLS) results of a single-equation estimator (Kmenta, 1971). Thus, the 3SLS estimates will be compared with the 2SLS estimates to determine the benefit of the simultaneous estimator versus the single equation estimator. However, comparing 3SLS results with GLS results will provide little additional information since the use of GLS versus 3SLS reflects a difference in the specification of the model.

Tables A-1 and A-2 provide 3SLS and 2SLS results, respectively. The coefficient values from 3SLS and 2SLS are different providing further positive evidence for the use of a systems estimator versus a single equation estimator. Changes in coefficient values were as high as 34% for relative military to civilian wage. The 3SLS estimation also increased the effect of a unit change in five of the seven coefficients for the continuous explanatory variables. The elasticity of the relative military to civilian wage for the 3SLS estimate of the NPS accession equation is 1.496, down from the 1.698 estimate from the GLS results but still comparable to the 1.590 DeVany and Saving (1982) estimate.

The 3SLS estimate generally provided poorer statistical results for the NPS accession equation in terms of explanatory power and statistical significance of the coefficients. This suggested that the endogeneity of quality and waiting time in the management of the accession flow of NPS recruits was not as much a factor during the October 1979 to September 1987 time period as was previously

Table A-1. Three Stage Least Squares Results

Number of observations: 96

Variable	Coefficient	T-stat.
NPS Accession Equation (R^2 = 0.6537):		
Constant	3.9060	3.89
QUAL	-0.1981	-4.53
WAIT	-0.0375	-1.92
EMP	-1.1533	-2.99
WR	0.4963	1.91
RECR	0.1297	2.15
NPSGOAL	-0.3021	-3.18
FLGOAL	-2.7189	-3.37
QTR1	-0.0655	-4.30
QTR3	-0.0683	-4.99
QTR4	-0.0263	-1.97
PS Accession Equation (R^2 = 0.5914):		
Constant	0.3926	3.69
PSEMP	-0.9398	-8.94
RLWR	0.2730	7.61
RECR	0.1162	9.24
PSGOAL	-0.0090	-2.24
QTR1	0.0033	0.85
QTR3	-0.0054	-1.40
QTR4	-0.0154	-3.85
First Term Reenlistment Equation (R^2 = 0.7876):		
Constant	0.4656	0.84
RLEMP1	-2.3698	-4.28
RLWR1	1.1886	10.41
DECM1	0.9098	3.78
EOUTS1	0.0310	6.24
QTR1	-0.0342	-1.72
QTR3	0.0162	0.85
QTR4	-0.0175	-0.89
Second Term Reenlistment Equation (R^2 = 0.8330):		
Constant	2.4766	8.34
RLEMP2	-2.8517	-11.07
RLWR2	0.4460	9.56
DECM2	0.4720	4.88
EOUTS2	0.0400	2.20
QTR1	-0.0050	-0.52
QTR3	-0.0025	-0.26
QTR4	-0.0082	-0.87

Table A-2. Two Stage Least Squares Results: NPS Accession Equation

Number of observations: 96

R^2: 0.6574

Variable	Coefficient	T-stat.
Constant	4.5597	3.9937
QUAL	-0.2396	-4.7979
WAIT	-0.0385	-1.7279
EMP	-1.2183	-2.8582
WR	0.3702	1.2708
RECR	0.0734	1.0894
NPSGOAL	-0.2457	-3.3660
FLGOAL	-3.0915	-2.3237
QTR1	-0.0717	-4.3178
QTR3	-0.0667	-4.5225
QTR4	-0.0261	-1.8195

economic, policy, and personnel management changes occurred in the 1980's which could have confounded the relationships between NPS accession flows and waiting time and quality. During the 1970's, the DEP was used as a personnel management tool, reaching its full usage in the 1980's when recruits could remain in the DEP for over 12 months prior to active duty. Recruiters were able to enter as much as 80 to 90 percent of a monthly accession goal into the DEP over several months prior to the actual month of active duty enlistment. As Table A-3 indicates, the recruiting goals were met every fiscal year from FY80 to FY89 with similar success on a monthly basis. When overall fiscal year recruiting goals can be met to the last recruit, as in FY86 through FY89, the primary responsibility for such accuracy lies within the DEP. Even the monthly fluctuations in the percent of the NPS recruiting goal met were minimal, dropping below 99% for only one month(95.2% for November 1985) during the 96 month sample period.

Since the NPS accession goals of the 1980's were always met with only minor difficulty and most NPS recruits entered the DEP, recruiters were able to manage and allocate waiting times to maximize the quality of NPS accession flows. For example, recruiters were able to be more flexible for high quality recruits by offering waiting times which would meet any recruit's desired length of wait. Low quality recruits would receive fewer waiting time options, since the pool of low quality recruits was larger and less desireable. In addition, the reduction in the force level in the latter 1980's and the improved first term reenlistment rates allowed recruiters to be more selective in the quality and timing of their NPS recruits since they were operating in a manpower surplus environment. Under less surplus conditions, the endogeneity of quality and waiting time would be more prominent in the flow of NPS recruits. Table A-4 presents values for QUAL (the proportion of AFQT 1's and 2's to all others) and the proportion of NPS recruits who entered the DEP from October 1979 through September 1987. The two series exhibited a 0.6111 simple correlation, indicating that as the proportion of AFQT 1's and 2's to all other recruits increased, the proportion of recruits entering the DEP rose. As the proportion of recruits entering the DEP rose, the average waiting time also rose. The simple correlation between WAIT and QUAL is 0.5310, which confirms the hypothesis that as the proportion of AFQT 1's and 2's to all other recruits increased, the average waiting time of recruits in the DEP rose.

Table A-3. Fiscal Year NPS Accession Flows and Recruiting Goals

Time Period	NPS Goal	Accession Flow	Percent of Goal Attained
FY77	72,500	72,510	100.01
FY78	68,000	68,025	100.04
FY79	68,000	66,616	97.96
FY80	70,741	71,838	101.55
FY81	76,113	76,918	101.06
FY82	67,474	67,538	100.15
FY83	60,489	60,489	100.00
FY84	59,817	60,011	100.32
FY85	65,000	65,017	100.03
FY86	64,400	64,400	100.00
FY87	55,000	55,000	100.00
FY88	41,200	41,200	100.00
FY89	43,450	43,450	100.00

Table A-4. QUAL and Proportion of DEP Recruits

Time Period	% in DEP	QUAL
1979.4	0.6320	0.7381
1980.1	0.6841	0.6944
1980.2	0.7898	0.6222
1980.3	0.7423	0.6377
1980.4	0.8020	0.7994
1981.1	0.8362	0.8808
1981.2	0.7831	0.7778
1981.3	0.7421	0.7371
1981.4	0.7856	0.8501
1982.1	0.7967	0.9050
1982.2	0.7930	0.8419
1982.3	0.7661	0.8917
1982.4	0.8209	1.0523
1983.1	0.8716	1.0934
1983.2	0.8831	1.1719
1983.3	0.8891	1.0717
1983.4	0.9050	1.0905
1984.1	0.8851	1.2005
1984.2	0.8737	1.0519
1984.3	0.8969	0.9110
1984.4	0.8735	0.7667
1985.1	0.8826	0.7210
1985.2	0.8593	0.7558
1985.3	0.8597	0.7147
1985.4	0.8720	0.7528
1986.1	0.8773	0.7729
1986.2	0.8715	0.9209
1986.3	0.9147	0.9040
1986.4	0.9011	1.0121
1987.1	0.9404	0.9893
1987.2	0.9192	1.0932
1987.3	0.8585	1.1706

APPENDIX B

Annual Civilian Noninstitutionalized Population

Calendar Year	Civilian Population (thousands)	Percent Change
1979	8,773	----
1980	8,737	0.41
1981	8,538	2.28
1982	8,276	3.0
1983	7,994	3.41
1984	7,708	3.58
1985	7,549	2.06
1986	7,546	0.04
1987	7,634	1.17

* U. S. GOVERNMENT PRINTING OFFICE: 1991--261-052/40068